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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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In re application of: Mervyn John ROSE et al.	Confirmation No.: 7787
Application No: 10/773,696	Group Art Unit: 2812
Filing Date: February 6, 2004	Examiner:
For: FIELD EMISSION BACKPLATE	Atty. Docket No.: 85170-5100

SUBMISSION OF CERTIFIED PRIORITY DOCUMENTS

Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450

Sir:

Applicants have claimed priority under 35 U.S.C. § 119 of Application Nos. GB 0119657.5 and GB 0119659.1, filed August 11, 2001in Great Britain. In support of this claim, certified copies of said applications are submitted herewith.

No fee or certification is believed to be due for this submission. Should any fees be required, however, please charge such fees to **Winston & Strawn LLP** Deposit Account No. 50-1814.

Respectfully submitted,

Date: 6/1/04

Allan A. Fanucci (Reg. No. 30,256)

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0119657.5 11 AUG 2001

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79820700 4

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GT F1/77 17.6.02

4. Title of the invention

IMPROVED FIELD EMISSION BACKPLATE

5. Name of your agent *(if you have one)*

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

CRUIKSHANK & FAIRWEATHER
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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

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CRUIKSHANK & FAIRWEATHER 10 August 2001

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DUPLICATE

IMPROVED FIELD EMISSION BACKPLATE

FIELD OF INVENTION

The present invention relates to a field emission backplate for use in a display, to a field emission display and to an associated method of manufacture. In particular the invention relates to a field emission display having a field emission backplate having a plurality of profiled tips formed by selective growth of crystalline silicon on a locally crystallised area.

BACKGROUND TO INVENTION

Flat panel displays are of immense importance in electronics. In current developments Active Matrix Liquid Crystal Displays (AMLCD) are beginning to challenge the dominance of Cathode Ray Tube (CRT) technology. AMLCD devices are non-emissive and require complex lithography. Filters and matching spectral backlights are required to produce colour. Further, there are many light losses and inherent complexity in AMLCD devices because of the non-linear nature of liquid crystal materials. This results in a display that is less bright than CRT with a smaller colour gamut and poorer viewing angle and contrast. Also, due to the non-emissive nature of the display, inefficient use of input electrical power is made

often with well over 70% of the energy being lost as non-useful energy.

Field emission displays based on conventional "Spindt Tip" technology, promised a solution to flat panel display problems. Field emission displayed (FEDs) are essentially flat cathode ray tube (CRT) devices. However, rather than one electron gun firing electrons at a phosphor on a screen through a shadow mask, the FED has tens or hundreds of individual tips in each display pixel. The tips are known as Spindt tips, after the inventor Cap Spindt. The process of fabrication relies on defining a pattern of holes in a gate metal by photolithography. An underlying insulator is then etched in an isotropic wet etch that "undercuts" leaving a well beneath the metal. A sacrificial layer, usually nickel is then evaporated on the surface at an oblique angle to ensure the well is not filled. The emitter material, usually tungsten or molybdenum is then evaporated through the holes in the well. As the evaporate metal builds up on the surface, on the sacrificial layer, it closes the hole as the thickness increases, and has the effect of providing an emitter tip in the well. The top metal is then removed by etching the sacrificial layer, leaving the tip, the well and the original gate metal. This forms the back plate of Spindt tips. A top plate containing a patterned phosphor is then placed relative to the backplate using spacers. The final device is evacuated to allow the emitted electrons a long mean free path.

The principle of field emission from micro-tips is governed by Fowler - Nordheim tunneling. The emission current, and therefore brightness of the display, depends then only on the current density, the number of tips and their sharpness, i.e. $I=J_{FN}\, n\alpha$.

Where n = number of tips, $\propto$ the tip sharpness and J_{FN} the Fowler-Nordheim tunnel current density.

The tips will provide a sharp electron source that will provide hot electron injection into a phosphor.

Unfortunately the extreme complication in fabrication has limited the use of this technology. Additionally crystal silicon emitter are limited by the wafer size.

Other thin-film materials may also be used for field emission. Carbon is the main contender with diamond, diamond like carbon and carbon nano-tubes also suitable. The use of diamond seemed a good choice, however, this is difficult to fabricate and also the mechanism of a supposed negative electron affinity which diamond was claimed to have is now being questioned.

An object of the present invention is to obviate or mitigate at least one of the aforementioned problems.

SUMMARY OF INVENTION

According to a first aspect of the present invention there is provided a field emission backplate comprising a plurality

of grown tips, the backplate being made substantially from semiconductor based material.

Preferably the plurality of tips are formed on a thin film of semiconductor based material.

It will be understood that in the context of the present invention the term "thin film" is used to define a film of a few nanometers, for example, 1 to 100nm, and typically 10nm.

Preferably the grown tips are "profiled", that is to say grown in a manner resulting in a sharp pointed shape. Conveniently, the tips are grown and etched simultaneously.

Conveniently, the semiconductor based material is silicon or an alloy thereof.

According to a second aspect of the present invention there is provided;

a field emission backplate comprising a planar member of substantially amorphous material and a plurality of tips of crystalline material thereon.

Preferably the tips are formed on crystalline areas of the planar member.

According to a third aspect of the invention there is provided a field emission backplate comprising a plurality of grown tips, the backplate being made substantially from a thin film silicon based material.

Preferably the plurality of tips are formed by the growth of crystalline silicon on plurality of crystallised areas of the thin film of amorphous silicon.

According to a fourth aspect of the invention there is provided a field emission device having a backplate comprising an array of profiled tips formed by the selective growth of crystalline semiconductor based material on a plurality of crystallised areas of a thin film of amorphous semiconductor based material.

Preferably the field emission device is a vacuum device wherein the emitter tips of the backplate act as an emission source in the device.

Conveniently, the field emission device comprises a substrate, a field emitting backplate, an evacuated space and a transparent window, e.g. thin film transparent metal, wherein the field emitting backplate is formed upon the substrate and the evacuated space is located between the field emitting backplate and the thin film transparent metal.

Alternatively, the field emission device further comprises a wide back gap light emitting material, e.g. light emitting polymer into which electrons from the emitter tips of the backplate are emitted.

Conveniently, the field emission device comprises a substrate, a field emitting backplate, on one side of which is formed a plurality of tips, a light emitting polymer and a thin film transparent metal wherein the field emitting backplate is formed upon the substrate, one surface of the light emitting polymer is disposed on the plurality of tips of the light

emitting backplate, the thin film transparent metal be disposed on the other surface of the light emitting polymer.

Conveniently the field emission device is a display device.

Preferably, the tips of the field emission backplate of the display device are of a density of at least 100 per square micron.

According to a fifth aspect of the invention there is provided a method of forming a field emission backplate comprising:-

depositing a thin film of amorphous semiconductor based material upon a substrate;

locally crystallising a plurality of areas of the thin film amorphous semiconductor based material; and

growing crystalline semiconductor based material upon each of the plurality of crystallised areas of thin film amorphous semiconductor based material.

Conveniently the thin film of amorphous semiconductor based material is deposited on a substrate e.g. by plasma enhanced chemical vapour deposition.

Preferably the plurality of areas of thin film amorphous semiconductor based material are crystallised by exposure to at least one pulse of laser interference pattern.

According to a sixth aspect of the invention there is provided a method of crystallising areas of thin film amorphous

semiconductor based material for use in a field emission backplate comprising:

forming a laser interferometer by splitting and recombining a laser beam;

placing the thin film of amorphous semiconductor based material in the plane of recombination of the laser beam;

locally crystallising areas of the thin film of amorphous semiconductor based m aterial by subjecting the thin film to at least one laser pulse, wherein the crystallised areas generated in the thin film amorphous semiconductor based material correspond to the interference pattern of the laser.

Preferably, for a backplate of amorphous semiconductor based material wherein the semiconductor based material is hydrogenated amorphous silicon, the laser operates at a wavelength of around 532nm to maximise absorption and preferably the laser is a Nd:YAG laser.

BRIEF DESCRIPTION OF DRAWINGS

These and other aspects of the invention will become apparent from the following description when taken in combination with the accompanying drawings, which are:-

Figure 1 a representation of a thin film of amorphous silicon onto which is projected a laser interference pattern;

Figure 2 a cross-section of a side profile of a grown crystalline silicon backplate according to a first embodiment of the present invention;

Figure 3 a schematic representation of a field emission device having crystalline silicon tips according to a second embodiment of the present invention;

Figure 4 a schematic representation of a field emission device having crystalline silicon tips according to a third embodiment of the present invention; and

Figure 5 a schematic representation of a field emission device having crystalline silicon tips according to a fourth embodiment of the present invention.

DETAILED DESCRIPTION OF DRAWINGS

With reference to Figure 1, there is shown a thin film of amorphous silicon disposed upon a substrate of aluminum wherein a pattern of dots cause by laser interference pattern can be seen upon a region of surface of the silicon. The thin film of amorphous silicon is disposed on the substrate of aluminum by plasma enhanced chemical vapour deposition (PECVD). A Nd:YAG pulse laser, having a pulsing duration in the region of 3 to 7 nanoseconds, is used to form an interferometer, with the beam being split and brought back together forming a pattern of dots. The thin film silicon layer is positioned in the plane in which the interference pattern of the laser is formed. The laser interference pattern acts upon the silicon layer creating areas, or dots, of crystallisation. A single pulse of laser the Nd:YAG is used to locally crystallise the region. The laser beam is synchronised with a step and repeat system in the

plane of the thin film silicon forming the laser spots and hence the crystallised dots to be distributed over the entire surface plate of the thin film silicon, thus allow a high density of tips to be made. By using this step and repeat system the plate may be made of any chosen size. An area of 30µm x 30µm is typical for an individual pixel, and hence a micro tip density of 300 x 300 which equals 9×10^4 per Red Green Blue (RGB) pixel will be achieved. Such density of emitters is of crucial importance as the emission current of a field emitting device depends on the number of tips and their sharpness.

A selective etch and growth process involving a dilute silane/hydrogen plasma is known to form micro crystalline silicon by allowing strained bonds within a silicon array, to be broken by the mobile hydrogen while deposited silicon atoms form thermodynamically stable crystalline sites. To form emitter tips upon the laser treated thin film silicon of Figure 1 the thin film silicon is subjected to a dilute silane/hydrogen plasma in a reactor. This process is applied to the PECVD deposited thin film silicon which has been laser treated wherein deposition of silicon atoms will only take place on a crystalline substrate therefore upon the crystallised dots of the thin film silicon. Amorphous or weak bonded areas of the structure are simultaneously etched. Continued growth has the effect of profiling the edges of the growing film where the etching effect is more dramatic. As, in

the arrangement of the present invention, the crystalline area is limited in size to less than 100nm, the aspect ratio is such that the edges converge. Therefore, each circular dot of 100nm or less of the emitter plate therefore effectively grows a profile tip. A cross section of the tips grown is shown in Figure 2. It is this profiling that leads to field enhancement of the emitter plate which therefore gives a low threshold (of around 15v/μm) for field emission and thus higher emitter current (i.e. in excess of 10^{-5} amps). The growth and etching processes are mediated by mobile hydrogen and the aspect ratio profiling etching leading to sharp tips over the entire growing surface of the plate of thin film silicon.

Also shown in Figure 2 are spacers which have been formed by using the pulsed laser to rest certain areas of the thin film silicon to create line or dot crystalline structure that have dimensions much bigger than those of the emitter dots. This results in a thicker deposited film being formed upon these crystalline areas. Thus spacers are grown at the time as the emitter tips, allowing placement of gates for three terminal devices.

As the emission current, and therefore the brightness of the display depends upon the current density, the number of tips, and their sharpness, according to $I=J_{FN}\, n\alpha$ the tips provide a sharp electron source that will provide hot electron injection into the light emitting layer of the device either through an evacuated space or into a wide band gap light

emitting material. The electron gains energy from the applied field, that is the field which is applied across the aluminum acts as an electrode.

A field emitting device configuration having crystallised silicon emitter tips formed as described with reference to Figures 1 and 2 is shown in Figure 3. The field emitting device is a vacuum device having grown spacers on the micron scale. The substrate is formed of aluminium onto which the thin film semiconductor based material, in this case thin film hydrogenated amorphous silicon, is disposed by PECVD. As has been detailed previously, a plurality of areas of the hydrogenated amorphous silicon is crystallised by a laser interferometer and, using the growth and etch system, tips and spacers are grown. A plate of patterned Indium Tin Oxide (ITO), disposed on a glass substrate, is arranged to sit on the grown spacers of the emitter backplate. The area between the emitter tips and the ITO is evacuated. The device may further be built into a triode configuration by the deposition of an insulator with a metal gate placed above.

A first alternative field emitting device is shown in Figure 4. In this configuration a field emitting device is arranged with a wide band-gap light emitting material, such as a polymer, disposed on top of the field emitting tips for use as the light emitting medium. A diode configuration is fabricated with a thin film transparent metal such as Indium Tin Oxide (ITO). The device has the field emitting backplate

of silicon and is formed on a substrate such as aluminium. A plate of patterned ITO on a glass substrate will have a thin film, in the order of many microns, of wide band gap light emitting polymer disposed upon it by, for example, screen printing. The light emitting polymer is then pressed onto the crystalline silicon tips of the backplane. A Al,-Si-polymer-ITO diode structure is thus formed with the polymer of the arrangement being cured upon baking the device to a temperature of approximately 100°C.

A second alternative field emitting device including a metal coated phospher layer member is shown in Figure 5. The other embodiments may similarly include a phospherescent layer (not shown).

Such devices are suitable for many display applications having low power consumption and being relatively simple to fabricate. The devices may also be used as the cathodes for high power transistors for microwave amplifiers in the sattelite and mobile communication markets.

Various modifications may be made to the invention as hereinbefore described without departing from the scope of the invention. For example, during the laser treatment of the thin film a amorphous silicon the use of a single laser pulse has been described in locally crystallising the region, however, a number of pulses may alternatively be used thus allowing energies as low as 20mJcm^{-2} to be used. Additionally, it has been described how the crystallisation of larger line or

dot structures can be used to grow spacers during the selective etch and growth process of the tips, however, silicon can also be grown in blocks on an insulator and thin film transistor devices for active address delineated in the same process. The process of crystallising the thin film amorphous silicon has been described by being performed by a pulsed laser, however, this may also be performed by other means such as intense electron beam irradiation or high energy ion beam/particle impact or even thermal annealing. The depositing of the thin film of amorphous silicon which may be intrinsic or doped n-type has been described by plasma enhanced chemical vapour deposition. However, the thin film may also be deposited by sputtering, evaporation or other such means. The substrates on which the thin film silicon has been deposited has been described as aluminum, however, may alternatively be metal such as molybdenum, chromium, or similar. Also in the example given in the description a Nd:YAG laser having 532nm wavelength is used to maximise absorption in silicon, however, other wavelengths can be used and in particular other wavelengths to maximise absorption in other appropriate semiconductor based materials can be used. The use of a transparent metal to form a diode configuration emitted device in the field is described, however, a suitable conducting polymer may alternatively be used.

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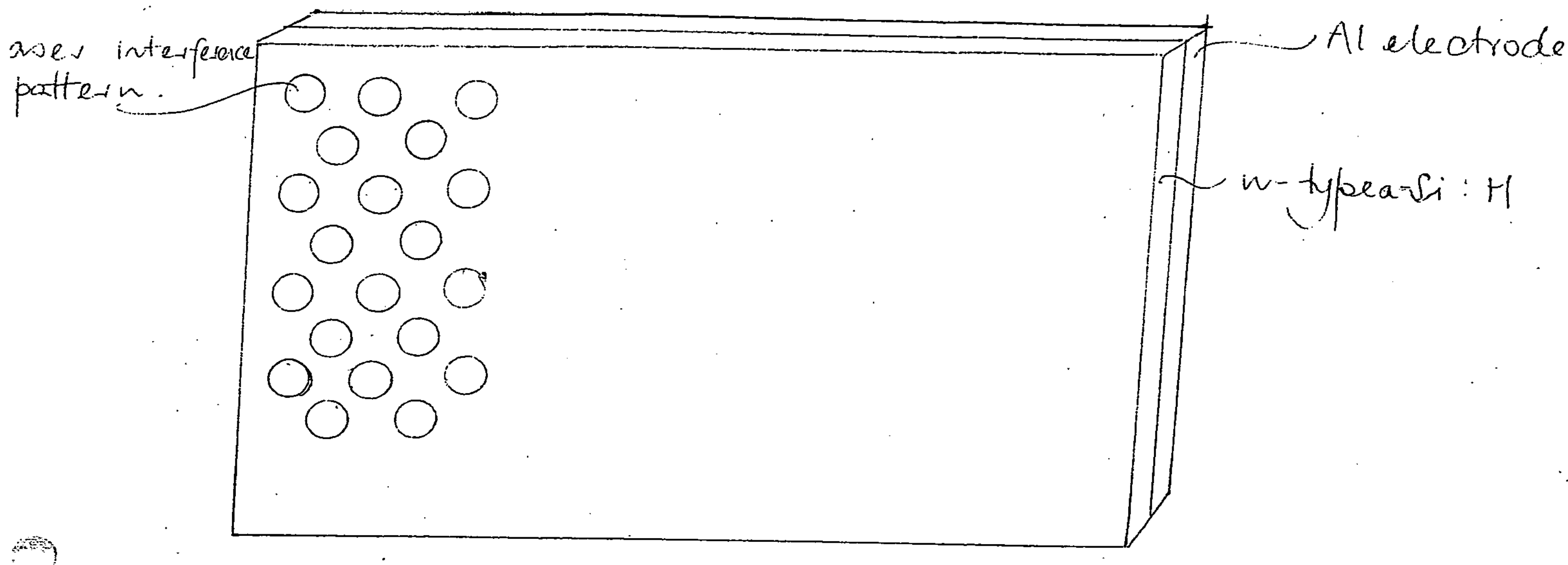

FIGURE 1.

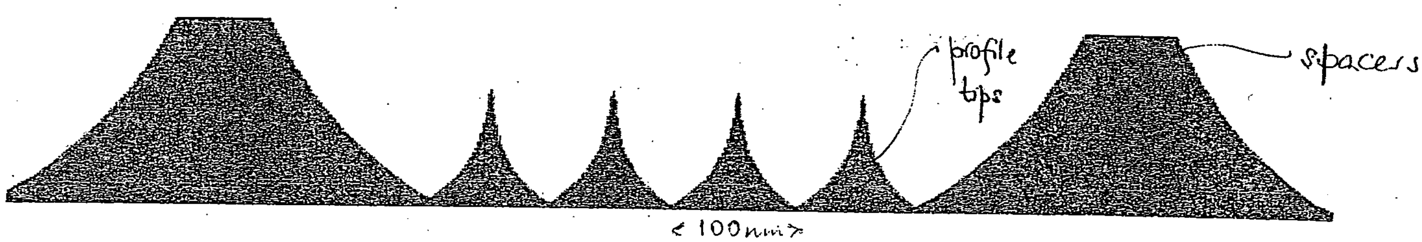

FIGURE 2

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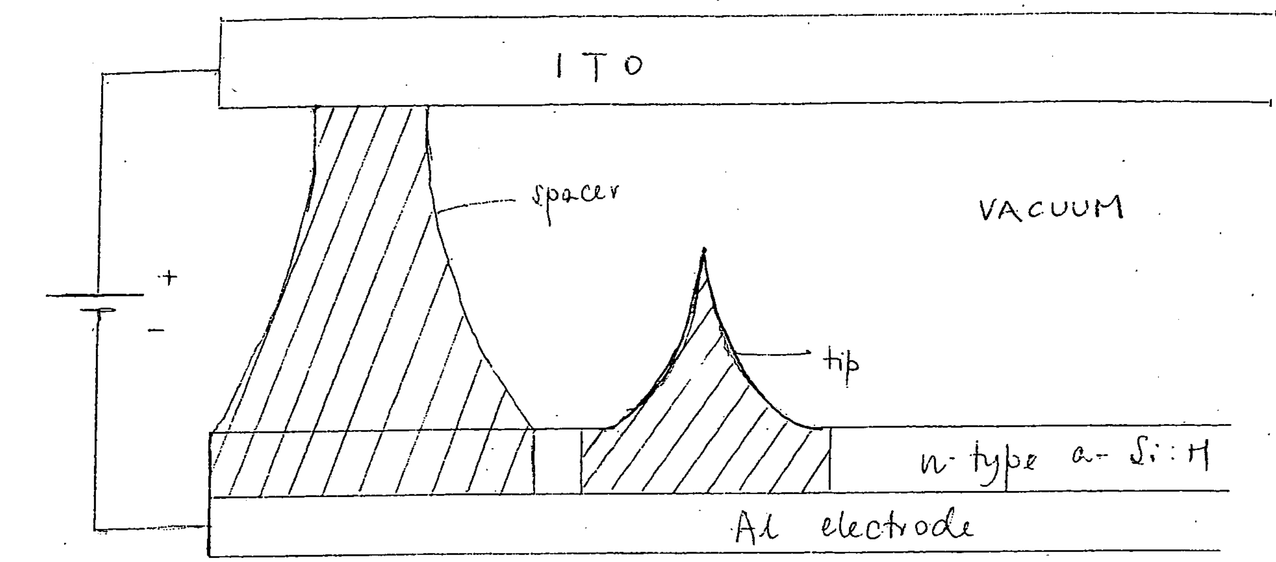

FIGURE 3

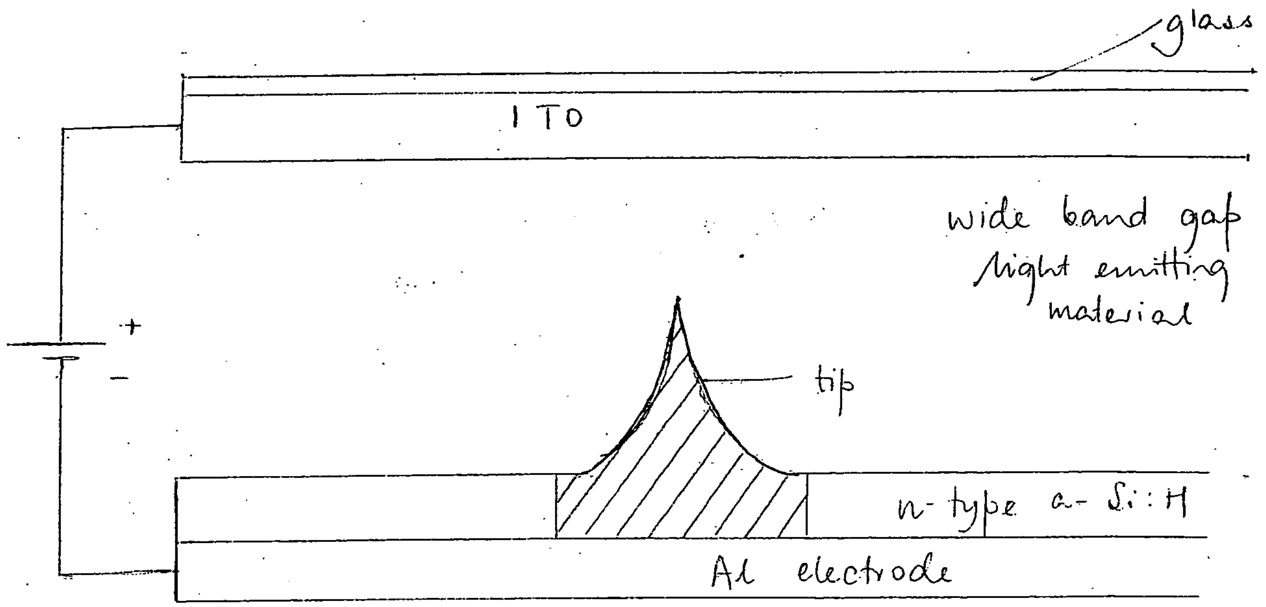

FIGURE 4.

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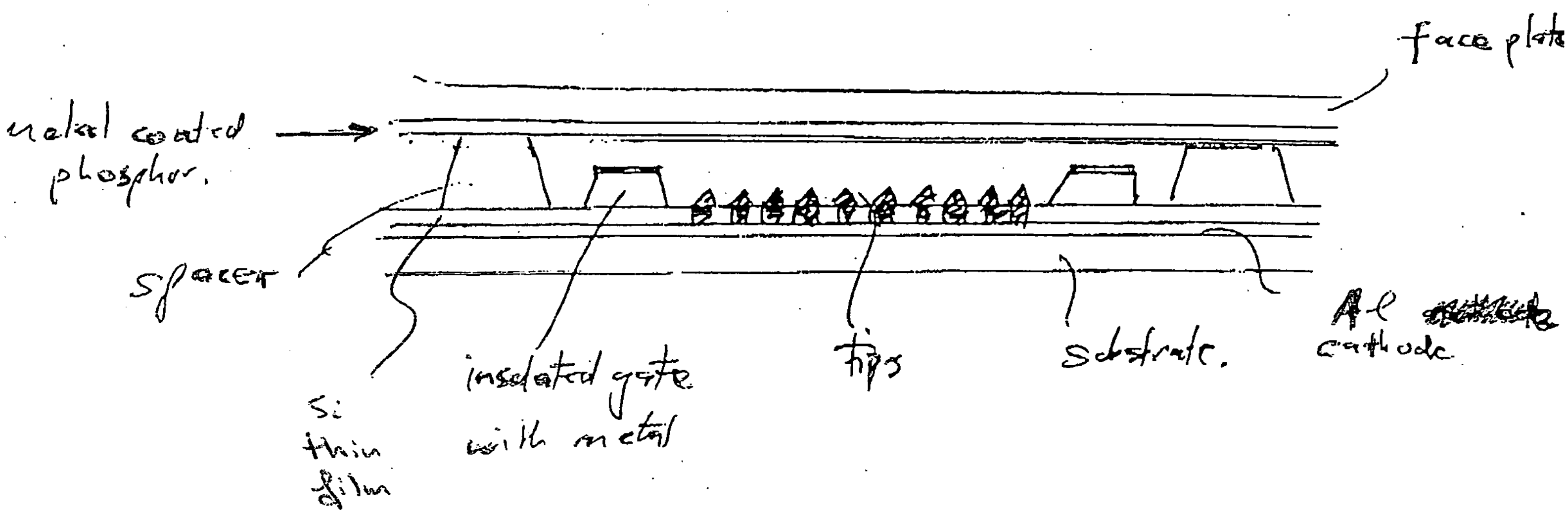
FIGURE 5.


face plate
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